IMAGE
INSTRUMENT SPECIFICATION
FOR THE
LOW ENERGY NEUTRAL ATOM IMAGER
LENA

Rev 2 Change 0

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SwRI Project No. 15-8089

Document No. 8089-ISLENA-01

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IMAGE

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Prepared by:	J. Lobell, LENA Systems Engineer	Date
Reviewed by:	T.E. Moore, LENA Lead Investigator	Date
Reviewed by:	M. B. Tapley, Observatory Systems Engineer	Date
Reviewed by:	B. P. Gupta, P. A. Engineer	Date
Approved by	W. C. Gibson, Project Manager	Date
Approved by:	J. L. Burch, Principal Investigator	Date

SOUTHWEST RESEARCH INSTITUTE
INSTRUMENTATION AND SPACE RESEARCH DIVISION
6220 CULEBRA ROAD
SAN ANTONIO, TEXAS 78238

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Document Revision History		
Revision	**Date**	**Changes**
Initial Release	February 25, 1997	
Second Release	April 28, 1997	Eliminated most TBD's and TBR's; updated to reflect changes since Confirmation Review
Rev 1 Ch 0	August 1, 1997	reflects changes prior to CDR
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LIST OF ACRONYMS

CG	Center of Gravity
CIDP	Central Instrument Data Processor
CCB	Configuration Control Board
CCR	Configuration Change Request
CGSE	Critical Ground Support Equipment
CS	Conversion Surface
EGSE	Electrical Ground Support Equipment
EID	Experiment Interface Document
ESA	Electrostatic Analyzer
FOV	Field Of View
GSE	Ground Support Equipment
IMAGE	Imager for Magnetopause-to-Aurora Global Exploration
LENA	Low Energy Neutral Atom
MGSE	Mechanical Ground Support Equipment
MIME	Multipurpose Internet Mail Extensions
S/C	Spacecraft

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Instrument Specification for the LENA

1. Scope, Objectives, and Description

1.2 Purpose

The purpose of this Instrument Specification is to document the technical and programmatic requirements of the spacecraft and mission in terms of compliance, detailed specification, and special requirements. This document will be used as the basis for spacecraft/instrument interface requirements, for functional and performance specifications, and for verification. The information in this document is as complete as possible. Where final numerical values are not available, best estimates are given and so noted. Items not applicable to an instrument are indicated by N/A.

1.2 Mission

LENA will produce data for the creation of images of the neutral atom population in the coronal region of the earth's magnetosphere. LENA shall image neutral hydrogen and oxygen atoms over two energy ranges: 10eV-300eV, and 50-750eV.

1.3 General Description

1.3.1 Hardware Description

The LENA instrument consists of the following components: a collimator- aperture, a charged particle rejection filter, a neutral-to-ion conversion surface, a surface work function monitor, an ion extraction lens, a steering voltage controller, an electrostatic analyzer, a time-of-flight (TOF) determination system, a command and data handling system (C&DH), a low-voltage power system (LVPS), various high-voltage power supplies, and spacecraft power and data interfaces.

The C&DH and LVPS systems are housed as a unit, separate from the rest of the instrument.

The collimator-aperture limits the FOV of the incoming neutral atoms. The interior surfaces of the collimator are shaped to minimize reflection of photons and the generation of secondary electrons and neutral atoms. An electrostatic filter in the collimator excludes charged particles with energies under 100keV. The aperture area is approximately 1 cm^2.

Light-trapping features of the lens, and selective blackening of some components of the optical system, combine to minimize entrance of photons into the EUV-sensitive TOF unit, thereby minimizing spurious "start" and "stop" pulses which appear as background flux.

The conversion surface converts incident neutrals to negatively-charged ions which are focussed on the TOF determination system by the ion extraction lens and ESA. The conversion surface is comprised of four trapezoidal polycrystalline tungsten facets. A relative figure-of-merit for the effective work function will be derived from measurements of the photoelectron current from the surface due to impingement of solar photons.

The ion extraction lens pulls negative ions away from the conversion surface, and along with the electrostatic analyzer, focusses them onto the entrance plane of the TOF optics unit. An adjustable “steering” potential controls the optics in such a say as to vary the energy range by a factor of 2.

The TOF system provides determination of mass and energy of incident ions. A "start" pulse is generated by a carbon foil-microchannelplate pair when an incident ion passes through the foil at the entrance of TOF optics unit, dislodging electrons in the foil. A "stop" pulse is generated when the ion strikes a microchannelplate at the back of the TOF unit. The mass of an ion of known energy is determined by measuring its transit time across the unit. Energy analysis is obtained from the position-sensing anodes behind the "start" microchannelplate array.

The C&DH system serves as the instrument’s power and data interface to the spacecraft. It receives and executes commands from the CIDP, compiles image and event data from the TOF electronics, collects engineering data from the instrument housekeeping system, formats the data, and transmits it to CIDP. It handles various instrument internal functions such as the control of high-voltage power supplies. It communicates with the CIDP via a serial data link.
In addition to these components, there is an HVPS for biasing the conversion surface and ion optics, a pair of HVPSs for the collimator charged particle rejection filter, an HVPS for each of the microchannelplate sets in the TOF unit, a 28V/30V DC/DC converter for power bus conditioning for the HVPSs, and 2 LVPSs for instrument command, data, and power control systems.

1.3.2 Software Description

Science data generated by LENA will consist of images generated once per spin. Each image will consist of a 12 x 45 pixel matrix, each pixel being comprised of 2 mass bins and 3 energy bins. The image information will be packetized and sent to the CIDP once per spin. The CIDP will provide any subsequent required data manipulation. See sections 3.2.2.3 and 3.2.2.4.

Software in LENA interprets commands from the CIDP.

Software in LENA is capable of sequencing instrument operations such as HVPS ramping. The software allows basic operations from the CIDP as well as macro-like commands which activate a stored sequence of basic operations.

Health of LENA is constantly monitored. The safing routine will command the LENA high voltage power supplies to their SAFE levels if overvoltage or overcurrent conditions are detected on any of the LENA power supplies. Excessive particle detector counts will also trigger the safing routing. All error condition thresholds are commandable.

1.3.3 Operational Modes

LENA will have three principal modes of operation:

1) Normal mode will consist of the generation of science (event and image) data and instrument housekeeping data. This mode will run during most of the orbit and will be the only science data mode. All science and HK data products can be enabled/disabled. Some of the products can be transmitted every several seconds. This flexibility permits tailoring of Normal mode for particular applications, such as test and integration environments.

2. Low Voltage mode. All processing functions enabled; HVPSs powered, but limited to $V_{max}/10$.

3. Safe mode. The HVPSs are commanded off. Engineering data will be collected and telemetered to the CIDP.

1.4 Operational Concepts

1.4.1 Ground Operations

The LENA GSE computer, as described in section 3.5.2, will be used for instrument-level ground operations. GSE/OS will be used for instrument commanding and data collection. LENA will be calibrated in a vacuum chamber at the neutral beam facility at the University of Denver. The LabView software package will be used to control the rotation stages which position the instrument inside the chamber. During vacuum and/or thermal vacuum testing, high voltage ramp-up will be carried out, as will simulated normal on-orbit science operation. The noise floor as a function of chamber pressure shall be calibrated for use as an indicator of normal operations during later thermal vacuum testing. During all Instrument-level operations, LENA shall be continuously purged as described in Section 3.4.6.5. At the start of vacuum tests the purge shall continue at least until the roughing pump has started. At the conclusion of vacuum tests, the chamber shall be back- filled with zero-grade or “five nines” Nitrogen, or “five nines” air, and purge shall be established before the chamber is opened.

1.4.2 Integrated System Testing

During integrated systems testing, LENA will be exercised to the fullest extent practicable given the conditions which prevail at test time. As a minimum, this will include exercises using the commanding, power control, science telemetry, and housekeeping telemetry systems. In addition, rudimentary testing of the high voltage power supplies may be executed. Ramp-up of the high voltage power supplies to at most their nominal operating voltages shall be conducted during payload thermal vacuum testing if acceptable environmental conditions prevail. During all payload-level operations, LENA shall be continuously purged as described in Section 3.4.6.5. At the start of vacuum tests, the purge shall continue at least until the roughing pump has started. At the conclusion of vacuum tests, the chamber shall be back-filled with purge gas. Purge shall be established before the chamber is opened.

1.4.3 On-Orbit Operations and Testing

LENA requires at least 5 days of outgassing time with the observatory in its nominal operating condition before any high voltage power supplies are activated. LENA requires only one turn-on operation unless it has been turned off for some reason, in which case the LENA team must be consulted before LENA is turned on again. Early operations and testing will consist principally of the turn-on and gradual increase of the outputs of the high-voltage power supplies over a period of 7 days, and the characterization of the CS monitoring system over a period of up to 30 days. No high voltage ramp-up shall take place during RPI antenna deployment operations, or at other times when monitoring or commandability are impaired. Routine operations consist mainly of collection of science data, occasional adjustment of power supply levels, and uploads for the refinement of data product definitions.

1.5 Organizational and Management Relationships

LENA will be designed and administered by Goddard Space Flight Center (GSFC) under the direction of Dr.Thomas E. Moore as Lead Investigator (LI), and John F. Laudadio as Instrument Manager. Systems engineering responsibility will be at GSFC under the direction of Jim Lobell.

2. Applicable Documents

2.1 Parent Documents

This document shall be governed by the Image System Specification, SwRI Document 8089-SYS-01. All requirements enumerated herein shall be traceable to the Image System Specification or to interface documents such as the Spacecraft to Payload Interface Control Document.

2.2 Government Furnished Property List

None.

2.3 Other Applicable Documents

GSFC

GSFC-696-LENA-001	LENA Quality Manual
GSFC-410-MIDEX-001	MIDEX Assurance Guidelines
GSFC-410-MIDEX-002	MIDEX Assurance Requirements

SwRI

80894000	LENA ICD drawing
PAIP-96-15-8089	IMAGE Performance Assurance Plan
15-8089-SYS-01	IMAGE System Specification
8089-VTP-01	Verification and Test Plan

Industry

ANSI/EIA-422	Interface between Data Terminal Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Interchange

NASA

311-INST-01	Instructions for EEE Parts Selection, Screening, and Qualification.

3. Requirements

3.1 Functional Requirements

The LENA instrument shall collect images by determining the mass, energy, and incident trajectory (azimuth and elevation angles) of incoming neutral atoms. The resolution, field of view, sensitivity, and other characteristics of the collected images shall be as described below and in accordance with the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) Level 1 Requirements Definition. It shall interface to the IMAGE Central Instrument Data Processor for telemetry and commanding as defined below and in the CIDP specification.

3.2 Performance Requirements

3.2.1 Optical System

3.2.1.1 General Description

The LENA optical system consists of the collimator, charged particle exclusion filter, aperture, conversion surface, ion extraction lens, electrostatic analyzer, and TOF optics unit.

3.2.1.2 Resolution

3.2.1.2.1 Pixel Resolution

LENA shall have a pixel resolution of 8^{o} x 8^{o} or better.

3.2.1.2.2 Energy Resolution

LENA shall have an energy resolution (delta-E/E) of 1.0.

3.2.1.2.3 Mass Discrimination

LENA shall be able to discriminate H from O neutral atoms.

3.2.1.3 Energy Ranges

LENA will operate in one of two energy range modes. In the low range, the energies analyzed will be in the range of 10-300eV, with energy bins centered at 20,65, and 200eV. In the high range, the energies analyzed will be in the range of 25-750eV, with energy bins centered at50,160, and 500eV.

3.2.1.4 Imaging Frequency

During normal science operations, LENA shall collect and transfer to the CIDP one image per spin, i.e. at a nominal rate of once every 120s .

3.2.1.5 Sensitivity

LENA shall have:

1. a pixel geometric factor of $7x10^{-4}$ counts/atom cm^{2} sr eV/eV.

2. a physical aperture of 1.17 cm^2

3. a pixel solid angle of $2X10^{-2}$ sr

The pixel geometric factor shall exceed $2x10^{-6}$ cm^2 sr eV/eV

3.2.1.6 Rejection of Noise

The LENA system shall reject noise background at the following rates:

UV photon rejection	10^{-7}
Electron rejection	10^{-10}
Ion rejection	10^{-8}

3.2.1.7 Field of View

See section 3.3.1.6.

3.2.2 Command and Data Handling system

3.2.2.1 Memory

LENA has a total of 96kbytes of SRAM. 64kbytes (two 32k x 8bit devices) will be used for science and housekeeping data. 32kbytes (one 32k x 8bit device) will be used for command queuing and microcontroller program storage.

3.2.2.2 Interface to TOF electronics

The C&DH subsystem shares a direct interface to the TOF Electronics. TOF subsystem configuration data and TOF output data are sent to the LENA C&DH via unidirectional serial links as defined in Appendix 1.

3.2.2.3 Processor Throughput

The main LENA processing load is handled by an Actel FPGA-based state machine. Command queuing is handled by a microcontroller. Instrument performance is dominated by the position-sensing electronics (PSE) processing speed, not by the data processing system. The PSE saturate without degradation of position accuracy, but with overflow.

3.2.2.4 Commanding Requirements

The C & DH system is capable of accepting at least one command every 100ms. It has a macro-like capability to assemble sets of commands into a procedure called by a single command from the CIDP. It accepts commands to control directly all functions listed in Section 3.3.4.5. It has a capability to be reprogrammed by accepting program information in command structures.

3.2.2.5 Data Collection Requirements

The C & DH system collects science data from the TOFE and position-sensing electronics. It accumulates up to 32 k words of data per two-minute Observatory revolution, including housekeeping telemetry. The average rate of data transfer to the CIDP shall not exceed 8kbytes per 120s spin. The C & DH integrates science data during each roll period to form images, and stores event data.

3.2.2.6 Command and Data Handling System Embedded Software

3.2.2.6.1 General Description

Software for the embedded controller will implement command scheduling by routing queued commands to the C&DH system at scheduled execution times.

3.2.2.6.2 Software Configurations

As mentioned above, the C & DH system shall have a macro-like capability to assemble sets of commands into a procedure called by a single command from the CIDP. It shall accept commands to control directly all functions listed in Section 3.3.4.5. It shall have a capability to be reprogrammed by accepting program information in command structures.

3.2.2.6.3 Operational Sequence and Characteristics

At power-up, program data is transferred from PROM to RAM. Time-tagged commands are transferred to the microcontroller's data space upon receipt from the CIDP. Commands are executed when their time-tag becomes current.

3.2.2.6.4 Memory Allocation

32k bytes of SRAM and 8k bytes of PROM are allocated to the microcontroller system. At power-up, the 8kb of PROM is copied to SRAM, from which the code is executed. The remaining 24k of SRAM is used for the storage of time-tagged commands, etc..

3.2.3 Low Voltage Power Supplies

3.2.3.1 General

LENA will employ off-the-shelf low-voltage power supplies manufactured by Lambda. The converters have been qualified by GSFC for space flight applications.

3.2.3.2 Transient (Turn-on and Turn-off) Performance

The LVPS shall exhibit a full load startup delay of less than 50 ms. Overshoot is less than 200 mV. The LVPS shall have a maximum inrush current less than half of what is specified in the IMAGE Spacecraft to Payload ICD Section 3.8.2 (currently 30 A peak for 10 microseconds). The LVPS may be turned off at any time without causing any damage to LENA.

3.2.4 High Voltage Power Supplies

3.2.4.1 General

There are five (5) high-voltage power supplies in LENA; the optics -20kV supply, two collimator bias supplies (one +8kV, one -8kV), and two 2.6kV MCP bias supplies (one for the "start" MCP, one for the "stop" MCP).

3.2.4.2 Safe-mode Performance

The high-voltage power supplies have three modes of powered operation which are selected by two dedicated control signals; “enable” and “V/10". When "enable" and “V/10” are both active, the high-voltage output is limited to its lowest commandable voltage, i.e. either 10% or 20% of nominal maximum voltage, depending on the supply. When "enable" is inactive, the output voltage will be zero, regardless of the state of “V/10”. When "V/10" is inactive and "enable" is active, the power supplies are fully operational.

3.2.4.3 Transient (Turn-on and Turn-off) Performance

The HVPSs shall have a maximum inrush current of 5 Amps.

3.2.4.4 HV Output Control

When fully armed, i.e. "V/10" is inactive, and "enable" is active, the HVPS output voltages obey a relationship of the form $V_{OUT} = A\,V_{IN} + V_0$ Where V_{IN} is the input control voltage, A is the gain factor for the respective HVPS, and V_0 is the nominal offset voltage. The control voltage varies from 0V to +10V in 256 equal steps.

3.3 Interfaces

3.3.1 Mechanical

3.3.1.1 Mechanical Dimensions

The outside envelope dimensions are 15.00" x 16.20" x 19.90".
See the LENA Mechanical ICD Drawing, #8089400

3.3.1.2 Mass Properties

The LENA mass shall not exceed 23.5 kg.

3.3.1.3 Instrument Center of Mass

The center of mass shall be located at x = 11.8", y = 7.87", z = 7.87" (**TBR**).
See MICD drawing for coordinate system.

3.3.1.4 Radiation Design

The LENA instrument provides its electronic components with a minimum shielding of .200" Al, yielding a total dose environment of 30kRAD. This includes the 0.020" (Al) shielding provided by IMAGE spacecraft structure.

3.3.1.5 Deployables

3.3.1.5. 1 Mechanical Properties of Instrument Deployables

None.

3.3.1.5.2 Deployable Latch

None.

3.3.1.5.3 Impact of Deployable on Instrument or Spacecraft CG

N/A

3.3.1.5.4 Method of Deployment

N/A

3.3.1.6 Field-of-View

The nominal, instantaneous science field of view of LENA is 90^{o} x 8^{o} FWHM. +/- 45^{o} in polar angle, and $+4.6^{o}/-6.5^{o}$ in azimuth, relative to a line normal to the spacecraft spin axis, and passing through the center of the LENA aperture. During one roll period, LENA shall sweep out a 90 degree (centered about the normal to the spin axis) by 360 degree total field of view. The FOV is astigmatic, having different foci for the elevation and azimuth. See the LENA Mechanical ICD for details. The clear FOV shall be $+/-50^{o}$ in polar angle, and +/- 10^{o} in azimuth.

3.3.1.7 Alignment

The maximum instrument alignment uncertainty shall be +/- 0.5^{o} in rotation (with respect to the star tracker) about any axis. The method of alignment and position measurement for the main instrument housing shall be by bolt hole placement in the payload deck. The instrument will be attached to the S/C deck by eight (8) bolts, size 10-32. Two opposite corners shall be located to tight tolerance.

3.3.1.8 Handling

The LENA flight instrument must be under purge at all times. The purge gas must be high-purity (<1ppm impurities), low-hydrocarbon air or nitrogen, e.g. “five nines” nitrogen. The flow rate shall be 2.5 liters/min when the collimator red-tag cover is in place, and 10 liters/min when the cover is not in place. Powderless gloves must be used at all times when handling LENA. These gloves shall be ESD-safe if any connectors on the LENA housing are not connected to a harness ,or are not capped in some fashion. LENA contains some very fragile components, including microchannelplates and carbon foils, and hence requires extremely gentle handling. The instrument must not be dropped, bumped, or exposed to any other form of acoustic or vibrational excitation without the express consent of the LENA Lead Investigator (LI).

3.3.1.9 Remove-Before-Flight Items

The remove-before-flight items for LENA will be the collimator/vent cover and the HV disarming plug. The collimator cover shall be removed only during thermal-vacuum testing, vibration testing, EMI testing, and within 24 hours of launch.
The high voltage disable plug shall be removed only for thermal vacuum testing and within 24 hours of launch. During payload and observatory integration and testing, the high voltage disable plug shall be installed at any time that a LENA representative is not present.

3.3.2 Electrical

3.3.2.1 Power

The LENA instrument shall not consume more than 15W of orbit average power. Its peak power shall not differ substantially from the average power. Table 3-1 describes the power supply requirements for the LENA instrument.

Table 3-1: Power/Voltage Summary for LENA

Input V (Volts)	Average I (ma) (@+34V)	Peak I (ma) @+28V	Average Pwr (watts) (@+28V)	Peak Pwr (watts) (@+34V)
+34+0/-12V	441mA	500mA	14W	15W

3.3.2.2 Power Profile and Peak Power

A nominal power of 15W is dissipated during normal science mode operation. The peak power dissipation shall occur during normal science mode when the HVPSs are at their highest output levels, and when event processing is taking place at a high rate.

3.3.2.3 Keep-Alive Power

None

3.3.2.4 Cables

LENA requires power and data cables to the CIDP power and data interfaces, and a cable from the HV disable connector to the laboratory HV disable connector. LENA also has a substantial intra-instrument harness, which requires tie-down to the s/c deck.

3.3.2.5 Connectors

The LENA spacecraft electrical interface consists of 1 power connector (9-position standard D-type), 1 command and data connector (15-position high density D-type), 1 HV disarming connector (9 position high density D-connector). These connectors are mounted on the C&DH box.

Also on the C&DH box is a 100-position male MDM connector for the HVPS interfaces, 4 nano-hex coax connectors for the PSE, 1 nano-hex connector for the electrometer, a 15-position male MDM connector for the TOF electronics power, a 31-position male MDM connector for the TOF data, and a 31-position female MDM connector for the thermistors.

3.3.2.6 Grounding

The +28V S/C bus return shall be isolated from the instrument chassis by 1 MOhm, min. Converter secondaries will be connected to chassis in a manner which minimizes current flow in the S/C structure. The instrument chassis shall be connected to the mounting shelf with a maximum bonding impedance of 0.025 Ohms.

3.3.2.7 Safety Connectors

LENA has 1 HV safety connector, described under “connectors” above.

3.3.2.8 Synchronization

Required synchronization signals pertaining to telemetry are defined in ANSI/EIA-422. LENA's power supplies are not synchronized. All switching power supplies shall operate at frequencies at or above 150kHz. No synchronization signals pertaining to other instruments shall be necessary, except as defined in Section 3.3.4.7

3.3.2.9 Pyrotechnics and Actuators

None.

3.3.2.10 Timing Requirements

LENA has no particular timing requirements outside of those delineated in the CIDP ICD.

3.3.3 Command and Data Handling

3.3.3.1 Power On/Off Commands

The S/C-level power on/off commands shall consist only of redundant +28V power on/off to the LENA instrument. Instrument-level commands issued by the CIDP are discussed in section 3.3.4.5.

3.3.3.2 Memory Load Commands

The CIDP upload message is used to patch the LENA microcontroller program and data RAM.

3.3.3.3 Serial Digital Data

Serial data consists of unbinned science (event) data, binned science (image) data, region of interest (ROI) data,"singles" (uncorrelated "start" or "stop") data, and housekeeping data. Data formats are shown Tables 3-2, 3-3, and 3-4. Indicated ApIDs are with the compression bit equal to zero, hence the byte containing the Ap ID (or "package type") would be greater by 80 hex with the compression bit set to one, i.e. 10 would become 90.

Table 3-2: Binned Data Segment Format (TBR for 12-vertical pixels) - ApID 10

LENA BINNED DATA SCIENCE DATA PACKET				
BYTE	BYTES	HEX	DESCRIPTION	UNITS
0-2	3	FEFA30	Sync pattern	
3	1	DC	Data Package Header	
4	1	90	Package Type Header	
5..6	2	1962	Byte Count	
7..10	4		MET	
11	1		Spin Vernier	~ sec
12..13	2		Number of valid events	counts
14..15	2		Species1 Start TOF	bin no.
16..17	2		Species1 Stop TOF	bin no.
18..19	2		Species2 Start TOF	bin no.
20..21	2		Species2 Stop TOF	bin no.
	2		Species1 counts[0,0,0]	counts
	2		Species2 counts[0,0,0]	counts
discontinuity				
	2		Species1 counts[44,11, 2]	counts
6500..6501	2		Species2 counts[44,11,2]	counts
6502	1		Checksum	

Table 3-3: Event Data Segment Format - ApID 20

LENA EVENT DATA SCIENCE DATA PACKET						
BYTE	BYTES	HEX	DESCRIPTION			UNITS
0..2	3	FEFA30	Sync pattern			
3..4	1	DC	Data Package Header			
5	1	A0	Package Type Header			
6..7	2		Byte Count			
7..10	4		MET			
11	1		Spin Vernier			~ sec
12..13	2		Sector 0 word count			counts
14..15	2		Event0 TOF (10 bits)	Plr Sector (4 bits, 0-11)	Energy (2 bits, 0-2)	bin no. | sctr | sctr
16..17	2		Event1 TOF	Plr Sector (4 bits, 0-11)	Energy (2 bits, 0-2)	bin no. | sctr | sctr

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			_			
	2		Sector 44 word count			Counts
	2		Event(x) TOF	Plr Sector (4 bits, 0-11)	Energy (2 bits, 0-2)	bin no. | sctr | sctr
N	1		Checksum			

Table 3-4: Singles Data Segment Format - ApID 30

SINGLES DATA SEGMENT FORMAT				
BYTE	BYTES	HEX	DEFINITION	UNITS
0..2	3	FEFA30	Sync Pattern	
3	1	DC	Data Package Header	
4	1	B0	Package Type Header	
5	2	00B9	Byte Count	
7	4		MET	
11	1		Spin Vernier	~ sec
12	2		Start Singles SpinSector0	counts
14	2		Stop Singles SpinSector0	counts
_				
189	2		Start Singles SpinSector 44	counts
190	2		Stop Singles SpinSector 44	counts
192	1		Checksum	

Table 3-5; ROI N Data Segment Format - ApID = 40 + 2*N

ROI N DATA SEGMENT FORMAT					
BYTE	BYTES	HEX	DEFINITION		UNITS
0..2	3	FEFA30	Sync Pattern		
3	1	DC	Data Package Header		
4	1	C0	Package Type Header		
5..6	2	0045	Package Byte Count		
7	4		MET		
11	1		Spin Vernier		~ sec
12 13 14 15	1 1 1 1		000AAAAA 000BBBBB CCCCDDDD 0000EEFF	TOF Start Bin TOF Stop Bin C=Polar Start Bin, D=Polar Stop Bin E = Engy Start Bin, F=Engy Stop Bin	bin no. bin no. bin no., bin no. bin no., bin no.
16	2		ROI N [0] (Parameterized by TOF)		counts
18	2		ROI N [1]		counts
_					
80	2		ROI N [31]		counts
82	1		Checksum		

3.3.3.4 Health and Safety

Instrument housekeeping data shall be transmitted to the CIDP every 2 minutes. Data format is shown in Table 3-6. Normal and quick-look housekeeping packets are implemented. Data is recorded at approximately 2-second intervals in the quick-look mode and at 2-minute intervals in the normal mode. The quick-look mode will be activated at instrument turn-on, during mode changes, and in test and calibration. The normal mode will be activated during steady state operation. Instrument state, including at the HVPS voltages and the LVPS subsystem temperatures, is sampled internally at the high rate for autonomous health and safety reasons. The CIDP shall monitor no more than 6 temperature sensors on the Payload Deck Plate beside the LENA instrument. In addition, the CIDP shall monitor the 28V input voltage to LENA, and the current on the 28V bus provided to LENA. The C&DH system shall monitor the conversion surface photoelectron current periodically during phases in which the sun is in LENA's FOV.

Table 3-6 Housekeeping Data Segment Format

NORMAL HOUSEKEEPING - APID 50

(transmitted once per spin, MSBit first)

BYTE OFFSET	DESCRIPTION		BITS
0..2	FEFA30	(SYNC PATTERN)	4
3	DC	Data Package Header)	8
4	50	(Package Header Type)	8
5..6	Byte Count		16
7..10	MET		32
	ERROR CONDITIONS		
11	SYSTEM_ERROR		1
	HVPS_MCP_START_VERR		1
	HVPS_MCP_STOP_VERR		1
	HVPS_COLLP_VERR		1
	HVPS_COLLN_VERR		1
	HVPS_OPTICS_VERR		1
	HVPS_MCP_START_IERR		1
	HVPS_MCP_STOP_IERR		1
12	HVPS_COLLP_IERR		1
	HVPS_COLLN_IERR		1
	HVPS_OPTICS_IERR		1
	HVPS_OPTICS_STEERING_VERR		1
	LVPS_30V_HVPS_VERR		1

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	LVPS_15VP_VERR	1
	LVPS_15VN_VERR	1
	LVPS_5VP_VERR	1
13	COMMAND_ERRORS	8
14	LVPS_5VN_VERR	1
	MEMORY_ERROR	1
	WATCHDOG_ERROR	1
	SELFTEST_ERROR	1
	TEMPERATURE_ERROR	1
	SYSTEM LEVEL STATUS	

	INTERNAL_SYNC_STATUS	1
	WATCHDOG_STATUS	1
	rsvd	1
15	SW_VERSION_	8
	DATA PACKET SELECTION	
16	SCI_BINNED_PACKET_STATUS	1
	SCI_DIR_EV_PACKET_STATUS	1
	SCI_SINGLES_PACKET_STATUS	1
	SCI_ROI_0_PACKET_STATUS	1
	SCI_ROI_1_PACKET_STATUS	1
	SCI_ROI_2_PACKET_STATUS	1
	SCI_ROI_3_PACKET_STATUS	1
	CMD_RECORD_HK_STATUS	1
17	QUICKNLOOK_HK_STATUS	1
	DIAGNOSTIC_HK_STATUS	1
	rsvd	6
	MASS BINNING CONFIGURATION	
18	TOF_BIN1_START	8
19	TOF_BIN1_STOP	8
20	TOF_BIN2_START	8
	TOF_BIN2_STOP	8
	TOF SUBSYSTEM CONFIGURATION	
	TOF_START_CFD_LEVEL	8
	TOF_STOP_CFD_LEVEL	8
	TOF_BIT_DELAY	8
25	TOF_BIT_STATUS	1
	HVPS CONFIGURATION	
	HVPS_SAFE_STATUS	1
	HVPS_RAMP_EN	1
	HVPS_MCP_START_EN	1

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	HVPS_MCP_STOP_EN	1
	HVPS_COLLP_EN	1
	HVPS_COLLN_EN	1
	HVPS_OPTICS_EN	1
26	HVPS_RAMP_RATE	8
	HVPS_MCP_START_CMD	8
	HVPS_MCP_STOP_CMD	8
	HVPS_COLLP_CMD	8
30	HVPS_COLLN_CMD	8
	HVPS_OPTICS_CMD	8
	HVPS_OPTICS_STEERING_CMD	8
SYSTEM LEVEL CONFIG		
33	SELFTEST_STATUS	1
	WDOG_STATUS	1
STATUS		
	SHUTTER_STATUS	1
	rsvd	5
34	COMMANDS_SENT	16
	COMMAND_EXECUTED	16
	COMMANDS_REJECTED	16
	PACKETS_SENT	16
	PACKETS_EXECUTED	16
	PACKETS_REJECTED	16
45	HVPS_MCP_START_VMON	8
	HVPS_MCP_STOP_VMON	8
	HVPS_COLLP_VMON	8
	HVPS_COLLN_VMON	8
50	HVPS_OPTICS_VMON	8
	HVPS_MCP_START_IMON	8
	HVPS_MCP_STOP_IMON	8
	HVPS_COLLP_IMON	8
	HVPS_COLLN_IMON	8
55	HVPS_OPTICS_IMON	8
	HVPS_STEERING_VMON	8
	SC_28V_VMON	8
	LVPS_30V_HVPS_VMON	8
	LVPS_15VP_VMON	8
60	LVPS_15VN_VMON	8
	LVPS_5VP_VMON	8
	LVPS_5VN_VMON	8
	LVPS_28V_SC_IMON	8
	LVPS_30V_HVPS_IMON	8

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65	LVPS_15VP_IMON	8
	LVPS_15VN_IMON	8
	LVPS_5VP_IMON	8
	LVPS_5VN_IMON	8
	SHUTTER_IMON	8
70	TEMPERATURE_T0	8
	TEMPERATURE_T1	8
	TEMPERATURE_T2	8
	TEMPERATURE_T3	8
	TEMPERATURE_T4	8
75	TEMPERATURE_T5	8
	TEMPERATURE_T6	8
	TEMPERATURE_T7	8
78	PARITY	8

COMMAND RECORD HOUSEKEEPING - APID 70
(transmitted once per spin when commanded, MSBit first)

BYTE OFFSET	DESCRIPTION		BITS
0..2	FEFA30	(SYNC PATTERN)	4
3	DC	(Data Package Header)	8
4	70	(Package Header Type)	8
5..6	Byte Count		16
7..10	MET		32
11..12	CMDS_SENT_BYTE_COUNT		16
13	cmds sent list		Byte count * 8
	CMDS_EXEC_BYTE_COUNT		16
	cmds executed list		Byte count * 8
	CMDS_REJ_BYTE_COUNT		16
	cmds rej list		Byte count * 8
	PARITY		8

MEMORY READ HOUSEKEEPING - APID 72
(transmitted when commanded, MSBit first)

BYTE OFFSET	DESCRIPTION		BITS
0..2	FEFA30	(SYNC_PATTERN)	24
3	DC	(Data Package Header)	8
4	72	(Package Header Type)	8
5..6	Byte Count		16
7..10	MET		32
11..12	START_ADDR		16
13	BYTE_OR_WORD_XFER | BYTE_COUNT		1 | 15
	Data follows		Byte count * 8
	_		
	PARITY		8

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DIAGNOSTIC HOUSEKEEPING - APID 75

(transmitted when commanded, MSBit first)

BYTE OFFSET	**DESCRIPTION**		BITS
0..2	FEFA30	(SYNC_PATTERN)	24
3	DC	(Data Package Header)	8
4	71	(Package Header Type)	8
5..6	Byte Count		16
7..10	MET		32
HVPS ERROR THRESHOLDS			
11	HVPS_MCP_START_IERR_THRSHLDP		8
	HVPS_MCP_START_IERR_THRSHLDN		8
	HVPS_MCP_STOP_IERR_THRSHLDP		8
	HVPS_MCP_STOP_IERR_THRSHLDN		8
15	HVPS_COLLP_IERR_THRSHLDP		8
	HVPS_COLLP_IERR_THRSHLDN		8
	HVPS_COLLN_IERR_THRSHLDP		8
	HVPS_COLLN_IERR_THRSHLDN		8
	HVPS_OPTICS_IERR_THRSHLDP		8
20	HVPS_OPTICS_IERR_THRSHLDN		8
	HVPS_OPTICS_STEERING_IERR_THRSHLDP		8
	HVPS_OPTICS_STEERING_IERR_THRSHLDN		8
	HVPS_MCP_START_VERR_THRSHLDP		8
	HVPS_MCP_START_VERR_THRSHLDN		8
25	HVPS_MCP_STOP_VERR_THRSHLDP		8
	HVPS_MCP_STOP_VERR_THRSHLDN		8
	HVPS_COLLP_VERR_THRSHLDP		8
	HVPS_COLLP_VERR_THRSHLDN		8
	HVPS_COLLN_VERR_THRSHLDP		8
30	HVPS_COLLN_VERR_THRSHLDN		8
	HVPS_OPTICS_VERR_THRSHLDP		8
	HVPS_OPTICS_VERR_THRSHLDN		8
	HVPS_OPTICS_STEERING_VERR_THRSHLDP		8
	HVPS_OPTICS_STEERING_VERR_THRSHLDN		8
LVPS ERROR THRESHOLDS			
35	LVPS_30V_HVPS_IERR_THRSHLDP		8
	LVPS_30V_HVPS_IERR_THRSHLDN		8
	LVPS_15VP_IERR_THRSHLDP		8
	LVPS_15VP_IERR_THRSHLDN		8

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	LVPS_15VN_IERR_THRSHLDP	8
40	LVPS_15VN_IERR_THRSHLDN	8
	LVPS_5VP_IERR_THRSHLDP	8
	LVPS_5VP_IERR_THRSHLDN	8
	LVPS_5VN_IERR_THRSHLDP	8
	LVPS_5VN_IERR_THRSHLDN	8
45	LVPS_30V_HVPS_VERR_THRSHLDP	8
	LVPS_30V_HVPS_VERR_THRSHLDN	8
	LVPS_P_15VERR_THRSHLDP	8
	LVPS_P_15VERR_THRSHLDN	8
	LVPS_15VN_VERR_THRSHLDP	8
50	LVPS_15VN_VERR_THRSHLDN	8
	LVPS_5VP_VERR_THRSHLDP	8
	LVPS_5VP_VERR_THRSHLDN	8
	LVPS_5VN_VERR_THRSHLDP	8
	LVPS_5VN_VERR_THRSHLDN	8
55	ERROR_DIAGNOSTIC_REG	32
59	PARITY	8

QUICK LOOK HOUSEKEEPING - APID 60

(transmitted ~ every 2 seconds when enabled, MSBit first)

BYTE OFFSET	DESCRIPTION		BITS
0..2	FEFA30	SYNC_PATTERN)	24
3	DC	(Data_Package_Header)	8
4	60	(Package_Header_Type)	8
5..6	Byte_Count		16
7..10	MET		32
	SYSTEM_ERRORS		
11	PACKET_PARITY_ERRORS		8
12	WATCHDOG_ERROR		1
	HVPS_ERROR_CONDITIONS		
	HVPS_MCP_START_VERR		1
	HVPS_MCP_STOP_VERR		1
	HVPS_COLLP_VERR		1
	HVPS_COLLN_VERR		1
	HVPS_OPTICS_VERR		1
	HVPS_MCP_START_IERR		1
	HVPS_MCP_STOP_IERR		1

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13	HVPS_COLLP_IERR	1
	HVPS_COLLN_IERR	1
	HVPS_OPTICS_IERR	1
	HVPS_OPTICS_STEERING_VERR	1
LVPS_ERROR_CONDITIONS		
	LVPS_30V_HVPS_VERR	1
	LVPS_15VP_VERR	1
	LVPS_15VN_VERR	1
	LVPS_5VP_VERR	1
14	LVPS_5VN_VERR	1
SYSTEM LEVEL_STATUS		
	SELF_TEST_STATUS	1
	rsvd	6
15	COMMANDS_SENT	8
	COMMAND_EXECUTED	8
HVPS_STATUS		
	HVPS_RAMP_RATE	8
	HVPS_SAFE_STATUS	1
	HVPS_MCP_START_EN	1
	HVPS_MCP_STOP_EN	1
	HVPS_COLLP_EN	1
	HVPS_COLLN_EN	1
	HVPS_OPTICS_EN	1
	rsvd	2
	HVPS_MCP_START_CMD	8
20	HVPS_MCP_STOP_CMD	8
	HVPS_COLLP_CMD	8
	HVPS_COLLN_CMD	8
	HVPS_OPTICS_CMD	8
	HVPS_MCP_START_VMON	8
25	HVPS_MCP_STOP_VMON	8
	HVPS_COLLP_VMON	8
	HVPS_COLLN_VMON	8
	HVPS_OPTICS_VMON	8
	HVPS_MCP_START_IMON	8
30	HVPS_MCP_STOP_IMON	8
	HVPS_COLLP_IMON	8
	HVPS_COLLN_IMON	8
	HVPS_OPTICS_IMON	8
	HVPS_STEERING_VMON	8

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LVPS_STATUS		
35	SC_28V_VMON	8
	LVPS_30V_HVPS_VMON	8
	LVPS_15VP_VMON	8
	LVPS_15VN_VMON	8
	LVPS_5VP_VMON	8
40	LVPS_5VN_VMON	8
	SC_28V_IMON	8
	LVPS_30V_HVPS_IMON	8
	LVPS_15VP_IMON	8
	LVPS_15VN_IMON	8
45	LVPS_5VP_IMON	8
	LVPS_5VN_IMON	8
47	PARITY	8

3.3.4 Central Instrument Data Processor

3.3.4.1 Data Transfer Rate

Once each spin, LENA shall transfer the following data to the CIDP. Science and housekeeping data are transferred to the CIDP at 38.4k baud.

1. Image data: 45 spin sectors x 12 polar zones x 2 masses x 3 energies x 2 bytes = 6480 bytes. This data is contained in the binned data packet. (Packet total = 6496 bytes)
2. Raw TOF position and energy data: Estimate a maximum of 55 events per spin sector or 55 x 45 spin sectors x 2 bytes = 4950 bytes. (Event Data Packet, total = 5046 bytes)
3. Individual TOF start or stop pulses: 180 bytes per spin. (Singles Packet, total = 186 bytes)
4. Region-of-Interest (ROI) spectra: 64 bytes per spin. (ROI0 Packet, total = 74 bytes)
5. Normal housekeeping data: 68 bytes per spin. (Nom_HK Packet, total = 72 bytes)

Total = 6496 + 5046 + 186 + 74 + 72 = 11,874 bytes per spin. Packet totals do not include the packet header and byte count which are removed by the CIDP. During any 13.5 hour orbit, the current total data transfer allocation is 26,542,080 bits. This translates to an average of 8k bytes/spin or approximately 0.5k bits per second. Compression of the data is therefore necessary to transfer both the image and event data for a spin. (8192 bytes/spin x .5 spin/min x 60 min/hr x 13.5 hr/orbit x 8 bits/byte = 26,542,080 bits/orbit)

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Additional ROI and housekeeping packets can be substituted for the above nominal transfer packets within the existing transfer allocation as deemed necessary by the LENA team. These packets are listed below:

ApID	Packet	Total bytes per spin
42	ROI1	74
44	ROI2	74
46	ROI3	74
75	Diagnostic HK	53
60	Quick Look HK	41
70	Command Record HK	3000
72	Memory Read HK	1033

3.3.4.2 CIDP Processing Requirements

The CIDP shall receive uncompressed data from LENA (data structure double buffered and read in once per revolution). The CIDP shall monitor LENA housekeeping data, commanding the instrument to safe mode if predefined operational limits are exceeded. (see 3.3.4.6)

3.3.4.3 Processing Rate

Each data packet defined in Section 3.3.4.2 shall be processed as defined in Section 3.3.4.2 before the arrival of the subsequent data packet.

3.3.4.4 Uncompressed Data Storage Requirements

During any 13.5 hr orbit, the current total data transfer allocation is 3,317,760 bytes. This is not sufficient to transfer all the data which LENA generates without data compression. The requirement for uncompressed data storage is dependant on the methods and rates employed by the CIDP for data compression and transmission.

3.3.4.5 Functions

With the application of power to the instrument, the LENA command and data handling system shall be activated, and the instrument will be in a safe configuration. Any changes to the configuration of the instrument shall be commanded from the CIDP. Control of power to subsystems and components within LENA shall be accomplished via commands from the CIDP to LENA's internal power control system. A list of the commands follows.

SYSTEM COMMANDS

1

COMMAND	BYTES	OPCODE [PARAMETERS] B7-B6: en/dsbl B5-B2: cmd B2-B0: parameter	UNITS	DESCRIPTION
MODE HEADER		9A		System command stem
L_SYS_MODE_ROM	2	9A 44		LENA operational mode set to ROM (default)
L_SYS_MODE_HVD	2	9A 45		LENA operational mode set to HV DISABLED
L_SYS_MODE_HVSF	2	9A 46		LENA operational mode set to HV SAFE
L_SYS_MODE_NRML	2	9A 47		LENA operational mode set to NORMAL
L_SYS_HKQL_EN	2	9A 89		Enable QUICK LOOK hk packet transmission
L_SYS_HKQL_DSBL	2	9A 49		Disable QUICK LOOK hk packet transmission
L_SYS_HKCM_EN	2	9A 8A		Enable COMMAND RECORD hk packet transmission
L_SYS_HKCM_DSBL	2	9A 4A		Disable COMMAND RECORD hk packet transmission
L_SYS_HKDG_EN	2	9A 8B		Enable DIAGNOSTIC hk packet transmission
L_SYS_HKDG_DSBL	2	9A 4B		Disable DIAGNOSTIC hk packet transmission
L_SYS_INST_RST	2	9A A8		Reset LENA
L_SYS _ERR_RST	2	9A AB		reset all error counters, registers and flags
L_SYS _BIN_EN	2	9A 8D		Enable transmission of Binned science data packet
L_SYS _BIN_DSBL	2	9A 4D		Disable transmission of Binned science data packet
L_SYS _EVENT_EN	2	9A 8E		Enable transmission of Event science data packet
L_SYS _EVENT_ DSBL	2	9A 4E		Disable transmission of Event science data packet
L_SYS _SNGLS_EN	2	9A 8F		Enable transmission of Singles science data packet

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L_SYS _SNGLS_ DSBL	2	9A 4F		Disable transmission of Singles science data packet
L_SYS_ROI_SEL	3	9A 4C [0000 $b_3b_2b_1b_0$]		Enable transmission of selected ROI segment(s) indicated by binary pattern [b_n]. "1" in selected field enables segment transfer. "0" disables segment transfer. b_0 - ROI 0 data (default=1) b_1 - ROI 1 data (default=0) b_2 - ROI 2 data (default=0) b_3 - ROI 3 data (default=0)
L_SYS_WDOG_EN	2	9A A1		Enable watchdog timer
L_SYS_WDOG_DSBL	2	9A 51		Disable watchdog timer
L_SYS_ISNC_EN	2	9A 95		Enable internal sync signal
L_SYS_ISNC_DSBL	2	9A 55		Disable internal sync signal
L_SYS_HVP_VTHR	7	9A 99 [V_{AA}] [V_{BB}] [V_{CC}] [V_{DD}] [V_{EE}]	TBD kV/bit TBD kV/bit TBD kV/bit TBD kV/bit TBD kV/bit	Set overvoltage thresholds for high voltage power supplies. Overvoltage limits V for each supply are parameterized, where 0< V < FFH. AA – MCP Start BB – MCP Stop CC – Collimator+ DD – Collimator- EE – Optics
L_SYS_HVP_ITHR	7	9A 9D [I_{AA}] [I_{BB}] [I_{CC}] [I_{DD}] [I_{EE}]	TBD kV/bit TBD kV/bit TBD kV/bit TBD kV/bit TBD kV/bit	Set overcurrent thresholds for high voltage power supplies. Overcurrent limits I for each supply are parameterized, where 0 < I< FFH. AA – MCP Start BB – MCP Stop CC – Collimator+ DD – Collimator- EE – Optics

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L_SYS_MEM_CHK	6	9A A2 AA AA BB BB		Check C&DH memory from 16-BIT address AAAA to BBBB

HVPS COMMANDS				
COMMAND	BYTES	OPCODE [PARAMETERS]	UNITS	DESCRIPTION
HVPS HEADER		A5		HVPS command stem
L_HVP_MSTR_EN	2	A5 80	-	Enable MCP Start HV power supply
L_HVP_MSTR_DSBL	2	A5 40	-	Disable MCP Start HV power supply
L_HVP_MSTP_EN	2	A5 81	-	Enable MCP Stop HV power supply
L_HVP_MSTP_DSBL	2	A5 41	-	Disable MCP Stop HV power supply
L_HVP_COLP_EN	2	A5 82	-	Enable Collimator Positive HV power supply
L_HVP_COLP_DSBL	2	A5 42	-	Disable Collimator Positive HV power supply
L_HVP_COLN_EN	2	A5 83	-	Enable Collimator Negative HV power supply
L_HVP_COLN_DSBL	2	A5 43	-	Disable Collimator Negative HV power supply
L_HVP_OPT_EN	2	A5 84	-	Enable Ion Optics HV power supply
L_HVP_OPT_DSBL	2	A5 44	-	Disable Ion Optics HV power supply
L_HVP_STR_EN	2	A5 85	-	Enable Optics Steering HV power supply
L_HVP_STR_DSBL	2	A5 45	-	Disable Optics Steering HV power supply
L_HVP_GBL SAFE	2	A5 1F	-	limit max HVPS output to 20% of F.S.
L_HVP_GBL_USAFE	2	A5 9F	-	max HVPS outputs are limited to 100% of F.S.
HVPS UPDATE PERIOD	4	A5 4F [P_1P_0]	k*sec/V	Pn is HEX code for HVPS update period. k = 1/200. [0000] disables update period (default).

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L_HVP_RAMP_EN 2 A5 97-Enable HVPS ramp up or ramp down.L_HVP_RAMP_DIS2A5 57-Suspend HVPS ramp up or ramp down. Default = enabled.L_HVP_MSTR_ CMD3A5 60[V]TBD kV/bitSend voltage command [V] hex to MCP Start HV power supply.0 < V _ FFHL_HVP_MSTP _ CMD	3	A5 61 [V]	TBD kV/bit	Send voltage command [V] hex to MCP Stop HV power supply. 0 < V _ FFH
L_HVP_COLP_ CMD	3	A5 62 [V]	TBD kV/bit	Send voltage command [V] hex to Collimator Positive HV power supply. 0 < V _ FFH
L_HVP_COLN_ CMD	3	A5 63 [V]	TBD kV/bit	Send voltage command [V] hex to Collimator Negative HV power supply. 0 < V _ FFH
L_HVP_OPT_ CMD	3	A5 64 [V]	TBD kV/bit	Send voltage command [V] hex to Ion Optics HV power supply. 0 < V _ FFH
L_HVP_STR_CMD	3	A5 65 [V]	TBD kV/bit	Send voltage command [V_1V_0] hex to Optics Steering HV power supply. 0 < V _ FFH
L_HVP_GBL_OFF	2	A5 6F	-	Execute HVPS shutdown macro (slew to 0V, safe, disable)

TOF COMMANDS				
COMMAND	BYTES	OPCODE [PARAMETERS]	UNITS	DESCRIPTION
TOF Header		B6		TOF command stem
L_TOF_MODE_STST	2	B6 33	-	Enable TOF start-stop mode (default)

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L_TOF_MODE_STRT	2	B6 03	-	Enable TOF start-only mode
L_TOF_BIN_STRT1	3	B6 21	nsec	Define start TOF definition for species_1 binning interval P – species1 start threshold 0 < P_FFH
L_TOF_BIN_STOP1	3	B6 22	nsec	Define stop definition for species_1 binning interval. P – species1 start threshold 0 < P_FFH
L_TOF_BIN_STRT2	3	B6 23 [P]	nsec	Define start TOF definition for species_2 binning interval. [P1P0] – species2 start threshold 0 < P_FFH
L_TOF_BIN_STOP2	3	B6 24 [P]	nsec	Define stop TOF definition for species_2 binning interval. P – species2 start threshold 0 < P_FFH, for all species
L_TOF_BIT_ON	2	B6 91	-	Enable TOF built-in-test mode
L_TOF_BIT_OFF	2	B6 51	-	Disable TOF built-in-test mode
L_TOF_BIT_STRB	2	B6 52	-	Route single strobe to TOF system. Active in bit mode only.
L_TOF_BIT_DELAY	3	B6 53 [P]	-	Define TOF BIT mode delay. Active in BIT mode only. 0 < P_FFH
L_TOF_TRSH_START	3	B6 61H [P]	-	Define TOF CFD start threshold. 0 < P_FFH
L_TOF_TRSH_STOP	3	B6 62H [P]	-	Define TOF CFD stop threshold. 0 < P_FH
L_TOF_STRB_FREQ	2	B6 [7 11p1 p0]	-	Define freq of TOF strobe by hex pattern pn. [pn] = 0 – 1 Hz 1 – 10 Hz 2 – 100 Hz 3 – 1 kHz

PSS COMMANDS			
COMMAND	BYTES	OPCODE [PARAMETERS]	DESCRIPTION

1

PSS HEADER		C7	PSS Command Stem
L_PSS_GAIN_LOW	2	C7 11	Set gain of position anodes to LOW gain (default).
L_PSS_GAIN_HIGH	2	C7 12	Set gain of position anodes to LOW gain (default).
L_PSS_DIG_STRB	2	C7 21	Digitize position data on all channels. Active in BIT mode only.
L_PSS_CHRG_HOLD	2	C7 31	Hold charge on all channels. Active in BIT mode only.
L_PSS_CHRG_DUMP	2	C7 32	Dump charge on all channels. Active in BIT mode only.
L_PSS_CHRG_ENB	2	C7 33	Enable position data acquisition on all channels. Active in BIT mode only.
L_PSS_MACR_STRB	2	C7 41	Sequentially hold, digitize, dump charge on all channels. Active in BIT mode only.

MEMORY COMMANDS			
COMMAND	BYTES	OPCODE [PARAMETERS]	DESCRIPTION
MEMORY ACCESS HEADER		E9	Memory Access Command Stem
L_MEM_WORD_RD	6	E9 0A [A_1A_0] [N_1N_0]	Read LENA memory space. Beginning at 16 bit hex address [A_1A_0], transfer [N_1N_0] (hex) bytes
L_MEM_WORD_WR	6+	E9 09 [A_1A_0] [N_1N_0] (data follows)	Write to LENA memory space. Beginning at 16 bit hex address [A_1A_0], transfer [N_1N_0] (hex) bytes
L_MEM_BYTE_RD	6	E9 06 [A_1A_0] [N_1N_0]	Read LENA memory space. Beginning at 16 bit hex address [A_1A_0], transfer [N_1N_0] (hex) bytes

1

L_MEM_BYTE_WR	6+	E9 05 [A_1A_0] [N_1N_0] (data follows)	Write LENA memory space. Beginning at 16 bit hex address [A_1A_0], transfer [N_1N_0] (hex) bytes

DISCRETE COMMANDS				
COMMAND	BYTES	OPCODE [PARAMETERS]	UNITS	DESCRIPTION
DISCRETE HEADER	1	98		Discrete command stem.
END OF DISCRETE COMMAND FRAME	1	BD		

3.3.4.6 Instrument Safe Requirements

Table 3-7 below lists the parameters that shall be monitored by the CIDP along with their respective limits, and actions to take should these limits be violated. The LENA turn-off procedure is as follows:

1. Execute Optics HVPS step-to-minimum output macro.
2. Power off Optics HVPS
3. Execute Start MCP HVPS step-to-minimum output macro.
4. Power off Start MCP HVPS
5. Execute Stop MCP HVPS step-to-minimum output macro.
6. Power off Stop MCP HVPS
7. Execute Collimator Positive HVPS step-to-minimum output macro.
8. Power off Collimator Positive HVPS
9. Execute Collimator Negative HVPS step-to-minimum output macro.
10. Power off Collimator Negative HVPS
11. Power off LENA instrument

Table 3-7: LENA Parameters to be monitored by CIDP

Monitor	**Limits**	**Action** if out of limits

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LENA +28V	+22V < V < +34V	execute LENA turn-off proc
LENA 28V BUS Current	I < 2 Amps	execute LENA turn-off proc
LENA Temp Mon	-20^o C < T < $+30^o$ C	execute LENA turn-off proc

3.3.4.7 Preferred Protocol for Serial Interface

RS422 protocol shall be implemented.

3.3.4.8 Roll Synchronization Pulse

LENA requires from the CIDP on a dedicated differential pair line a pulse every 0.1 degrees of observatory rotation with respect to the nadir direction (nominally every 33.3 milliseconds). The pulse train shall include a double pulse issued once per roll (nominally every 2 minutes) when the Observatory -x axis is pointed at the nadir. The pulse train shall also include a triple pulse when the -x direction is closest to the sun. The double pulse will serve as the major frame delimiter, and minor frame delimiters will be counted down from the single pulses. These signals shall be available during I&T, as well as during on-orbit operations. When the observatory is at roll rates more than +/- 5% from the nominal roll rate, the CIDP shall issue commands to insure that LENA is sun-safe and shall maintain the pulse train at the nominal rate to facilitate commanding and housekeeping telemetry collection.

3.3.5 Thermal

3.3.5.1 Thermal Design Requirements

The thermal control system shall maintain acceptable operating temperatures for the TOF optics, TOFE, C&DH system, conversion surface and vicinity, and high voltage power supplies.

3.3.5.2 Thermal Design Concept

1) Heat Extraction Paths.

Heat dissipated by the HVPSs, IXL resistive dividers, steering voltage controller, and TOF electronics is conducted to the radiating surfaces of the collimator. The LENA main optics unit is thermally isolated from the payload deck. The C&DH housing, which also houses the low-voltage power system, is conductively coupled to the payload deck.

2) Description of Hot Spots.

The C&DH/LVPS system dissipates 6W, and is the warmest portion of the instrument under normal operating conditions. The remaining 8W of nominal operating power is dissipated by the TOF electronics, the five HVPSs, the IXL resistive dividers, and steering voltage controller.

3) Description of Cold Spots.
The coldest portion of the instrument is the collimator, particularly the portion outside the spacecraft. The collimator radiating surfaces are nominally at 0^{o} C at beginning of life and 10^{o} C after 2 years.

4) Average Temperature Seen by Spacecraft.
The average temperature of the LENA box inside the spacecraft is cooler than 20 C after 2 years.

5) Desired Temperature.
The desired temperature for the optics cavity, including the conversion surface, ion extraction lens, and ESA during the normal operating mode, is 0^{o}C. The maximum working temperature of this portion of the instrument is 20^{o} C. The desired temperature of the electronics modules is 20^{o}C.

6) Thermal Model.
Thermal analysis of the LENA instrument shall be performed by using SINDA and TRASYS. The thermal mathematical model of the LENA instrument has 50 nodes. It will be delivered to the spacecraft contractor for integration into the spacecraft thermal model.

3.3.5.3 Thermal Interfaces

1) Thermal Mounting Details
The LENA main optics housing is thermally isolated from the IMAGE spacecraft internal thermal environment by plastic standoffs and MLI blankets. It is radiatively coupled to the s/c ambient environment via the collimator. The instrument box is mounted to the spacecraft equipment shelf through eight mounting feet, under which are plastic standoffs. The LENA collimator protrudes about 4.5 cm (3") through the solar arrays to the exterior of the spacecraft.

2) Thermal Conductance between LENA Box and Equipment Shelf.
The conduction coupling between the instrument box and the spacecraft equipment shelf is minimized by the plastic standoffs. The radiation coupling between the instrument box and the spacecraft interior is minimized by the MLI blankets.

3.3.5.4 Heaters

LENA has a 10W survival heater powered through a thermostatic switch. The anticipated average survival heater power dissipation is 5W during periods when the heater is required to maintain specified temperatures.

3.3.5.5 Thermal Finish

The exterior surfaces of the LENA box inside the IMAGE spacecraft shall be Dow-9. Surfaces of the collimator outside the spacecraft shall have GSFC conductive composite coating ($ITO/SiO_x/Al_2O_3/Ag$), which has a low absorptance and a high emissivity, and is electrically conductive.

3.3.5.6 Temperature Range

The temperature limits and stability shall be as follows.

Operational:	-20^{o} C < T < $+30^{o}$ C	at payload deck interface
Non-operational:	-30^{o} C < T < $+40^{o}$ C	at payload deck interface

3.3.5.7 Temperature Monitoring

A temperature sensor shall be placed on the equipment shelf close to the LENA mounting feet. It monitors the mounting interface temperature during the spacecraft level thermal balance and thermal vacuum test. In addition, temperature sensors will be located on each electronic housing, and on the housing near the conversion surface.

3.3.5.8 Thermal Analysis and Predictions

During normal operations, the LENA dissipates 14W. After 2 years, the worst case hot temperature of the instrument is the C&DH electronics, which approach 40^{o} C. Under these conditions, the exposed portion of the collimator is 26 ^{o}C.

3.4 Other Design Requirements3.4.1 Environments

LENA shall survive and operate normally as appropriate in the environments described in the IMAGE System Specification, Section 3.1.2.1.

3.4.2 Life

LENA shall be designed for a minimum life of 2 years in testing, 2 years shelf storage, and 2 years on-orbit operations.

3.4.3 Reliability

Design practices shall be used for LENA which maximize reliability within other mission constraints.

3.4.4 Maintainability and Storage

LENA's design shall, to the extent practical, facilitate refurbishment without adverse effect to the instrument. LENA shall be stored under conditions as described in Section 3.3.5.6. LENA shall be bagged and maintained under a constant purge as described in Section 3.4.6.5 during storage. Temperature changes in the LENA storage area shall be no faster than 5 degrees C per hour.

3.4.5 Safety

3.4.5.1 Transportation Safety

During transportation, LENA shall have no exposed high voltage components nor sharp edges. LENA shall be placed into a safe condition in its travel container for shipping. During transportation, LENA shall be maintained under purge at all times.

3.4.5.2 GSE Safety

The LENA GSE shall have no exposed high voltage components nor sharp edges. The Collimator cover shall have a bright red anodized finish.

3.4.6 Special Materials & Processes Constraints

3.4.6.1 Sensitive Components

LENA contains the following sensitive components. Operations and processes shall be such as to prevent damage to these components.

1) microchannelplates (MCPs): sensitive to organics, humidity, and particulate contamination
2) carbon foil: sensitive to mechanical and acoustical disturbance
3) conversion surface: sensitive to chemical and particulate contamination
4) HV system: sensitive to particulate contamination and humidity
5) electronic systems: sensitive to ESD

3.4.6.2 Limits

3 hours total lifetime purge interruption, except with purge gas backfill in sealed container.

3.4.6.3 Protection

Class 10,000 or better clean room shall be used. Purging or strict environmental control shall be used at all times.

3.4.6.4 Purge Connectors

There shall be two purge connectors on LENA; one for the nominal flow rate of 5SCFH, and one for the high flow rate of 50SCFH. The purge connectors shall be CPC 1/8 inch F, QC, Delrin Part No. PMDC 10-02. They shall be located on the side of the instrument housing opposite the collimator (see LENA ICD drawing, #GE1309000).

3.4.6.5 Purging

"Zero-grade" or "5-nines" N_2 required at all times. Flow rates are 2.5 liters/min with the collimator cover on, and 10 liters/min with the cover removed.

3.5 Special Ground Support Equipment (GSE)

3.5.1 Mechanical GSE

LENA shall require the following mechanical GSE:

1. collimator cover
2. shipping containers (2)
3. instrument purge system

3.5.2 Electrical GSE

LENA shall require the following electrical GSE:

1. BSI Pentium-based portable PC with Windows 95 OS.
2. +28V DC power supply
3. High voltage disable plug

3.6 Operations Support and Training

During instrument level testing, the LENA team shall conduct a mission walk-through. During payload level testing the LENA team shall participate (including having a representative at SwRI) in a mission walk-through. During launch and early orbit operations, LENA shall have representatives including at least the Systems Engineer and the Electronics REE at the SMOC during all LENA critical operations.

3.7 Special Considerations

None.

4. Verification

4.1 General

All instrument-level verification activities for the LENA program shall be the responsibility of GSFC. Instrument level verification activities shall take place at GSFC and the University of Denver.

All payload-level verification activities shall be the responsibility of SwRI. Payload-level verification activities shall take place at SwRI and at GSFC or LMMS for thermal vacuum testing. GSFC may take advantage of the opportunity to do an internal inspection during refurbishment if such inspection is needed for verifications.

4.1.1 Relationship to Management Reviews

4.1.1.1 Relationship to Design Reviews

Verification activities start during the functional testing of engineering units.

4.1.1.2 Verification Accomplishment

At a minimum, verification will be reviewed at Instrument CDR, at Mission CDR, and at S/C pre-ship review.

4.1.2 Test/Equipment Failure

Test procedures shall specify requirements for test equipment calibration. Should test equipment fail during the performance of a test, the test shall be halted. A Nonconformance Report describing the nature of the failure and requirements for failure analysis shall be prepared. The failure analysis shall address these issues:

> <u>Status of the test procedure</u> - whether to continue from the point of test equipment failure or to restart the test from beginning. This determination shall be based upon whether the test equipment failure has the potential to compromise the test results gathered prior to the failure.
>
> Whether, for purposes of this test, to repair or replace the failed test equipment. If the test equipment is repaired, identify any actions that need to be taken to restore confidence in the integrity of the test equipment.

4.2 Verification Method Selection

The default verification method of choice is test. Only those activities which cannot be verified by test, or which present a danger of damage to the instrument hardware will be performed by demonstration, analysis, inspection, or similarity assessment. See SwRI document 8089-VTP-01 for details of verification activities.

4.2.1 Test

A test provides a quantitative method to verify conformance of functional characteristics with specified requirements. The object being tested performs its required functions as a test engineer monitors and analyzes its performance to ensure it meets specified performance levels. A test is associated with specific pass or fail criteria; a test is successful when the criteria are met (i.e., acceptance criteria).

4.2.2 Demonstration

A demonstration is a functional qualitative (test) verification method that evaluates functional characteristics without the need to evaluate detailed design performance. A demonstration is generally used to verify functional requirements and generally does not require precision test equipment.

4.2.3 Analysis

An analysis is an engineering assessment or mathematical verification method that uses techniques and tools such as math models, prior test data, simulations, or analytical assessments to confirm compliance with specification requirements with appropriate margin. Whenever possible, test data are used to validate the analytical techniques used for verification. Analysis is mainly used to verify performance where a test is not practical or feasible. Analysis also includes processing accumulated data, including data from lower levels and other verification methods, to conclude that a complex, integrated system meets its top-level performance requirements.

4.2.4 Inspection

Inspection is a verification method in which examination or measurement of product characteristics or the review of design, production, or test documentation determines compliance with specification requirements. Inspection of design, production, or test documentation involves engineering review and buyoff and is not performed against test procedures. Inspections are nondestructive and consist of visual observation or simple measurement.

4.2.5 Similarity Assessment

Similarity is employed where the design of hardware or software is identical to or sufficiently similar to proven hardware or software, so that further verification is unnecessary.

4.3 Phased Verification Requirements

4.3.1 Instrument Development, Qualification, and Acceptance

The verification activities executed during instrument development and under the aegis of the instrument developer are shown in the "I" column of Table 4-1.

4.3.2 Payload Integration/Testing

The verification activities executed during payload integration and testing and under the aegis of Southwest Research Institute are shown in the "P" column of Table 4-1.

4.3.3 Observatory Integration/Testing

The verification activities executed during spacecraft to payload integration and during observatory testing and under the aegis of LMMS are shown in the "O" column of Table 4-1.

4.3.4 Flight/Mission Operations

No verification will be necessary during Flight/Mission operations. Some calibration activities will be conducted on orbit, and tests of system operations such as the sun-warning pulse from the CIDP may be carried out, but primary verification that all specifications are met will be prior to launch.

4.4 Verification Cross Reference Index

Table 4-1 contains the verification matrix used to identify the level and method of requirement verification defined in this specification. The codes used as required for delineating the verification matrix, are as follows:

Method:
- T = Test (4.2.1)
- D = Demonstration (4.2.2)
- A = Analysis (4.2.3)
- I = Inspection (4.2.4)
- S = Similarity Assessment (4.2.5)

Level:
- I = Instrument Level (4.3.1)
- P = Payload Integration Level (4.3.2)
- O = Observatory Level (4.3.3)

Note that full verification of all requirements may not be possible given the prevailing environmental conditions for a given test at a given level. An entry in the table below implies at least partial verification. Testing at all levels will be as comprehensive as prevailing conditions permit, given the restrictions imposed by the various instrument sensitivities. For example, full performance testing of high-voltage power supplies requires that LENA be at 10^{-6}T for at least 24 hours prior to activation and during the test.

1

Table 4-1: LENA Verification Matrix

Requirement	I	P	O
3.1 Functional Requirements	T		A
3.2 Performance Requirements	-	-	-
3.2.1 Optical System	-	-	-
3.2.1.1 General Description	I	I	-
3.2.1.2 Resolution	-	-	-
3.2.1.2.1 Pixel Resolution	T	-	-
3.2.1.2.2 Energy Resolution	T	-	-
3.2.1.2.3 Discrimination	T	-	-
3.2.1.3 Energy Range	T	-	-
3.2.1.4 Imaging Frequency	D	D	D
3.2.1.5 Sensitivity	T	-	-
3.2.1.6 Rejection of Noise	T	-	-
3.2.1.7 Field of View	A	-	A
3.2.2 C&DH	-	-	-
3.2.2.1 Memory	I,T	-	-
3.2.2.2 Interface to TOF Electronics	T	T	T
3.2.2.3 Processor Throughput	T	-	-
3.2.2.4 Commanding Requirements	T	T	T
3.2.2.5 Data Collection Requirements	T	T	T
3.2.2.6 C&DH System Embedded Software	-	-	-
3.2.2.6.1 General Description	T		
3.2.2.6.2 Software Configurations	T	T	T
3.2.2.6.3 Operational Sequence and Characteristics	T	T	T
3.2.2.6.4 Memory Allocation	T	T	T
3.2.3 Low Voltage Supplies	-	-	-
3.2.3.1 General	I	-	-
3.2.3.2 Transient Performance	T	-	-
3.2.4 High Voltage Supplies	-	-	-
3.2.4.1 General	I	I	I
3.2.4.2 Safe-mode Performance	T	T	T
3.2.4.3 Transient (Turn-on and Turn-off) Performance	T	-	-
3.2.4.4 HV Output control	T	-	T
3.3 Interfaces	-	-	-
3.3.1 Mechanical	-	-	-
3.3.1.1 Mechanical Dimensions	T	-	-
3.3.1.2 Mass Properties	T	-	-
3.3.1.3 Instrument Center of Mass	A	-	-
3.3.1.4 Radiation Design	A	-	-
3.3.1.5 Deployables	-	-	-
3.3.1.5.1 Mechanical Properties of Instrument Deployables	-	-	-

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3.3.1.5.2 Deployable Latches	n/a	n/a	n/a
3.3.1.5.3 Impact of Deployable on Instrument or Spacecraft CG	n/a	n/a	n/a
3.3.1.5.4 Method of Deployment	-	-	-
3.3.1.6 Field-of-View	A	-	A
3.3.1.7 Alignment	-	-	A
3.3.1.8 Handling	T	-	T
3.3.1.9 Remove-Before-Flight Items	-	-	I
3.3.2 Electrical	-	-	-
3.3.2.1 Power	T	T	T
3.3.2.2 Power Profile and Peak Power	T	T	T
3.3.2.3 Keep-Alive Power	n/a	n/a	n/a
3.3.2.4 Cables	I,T	I,T	I,T
3.3.2.5 Connectors	I	I	I
3.3.2.6 Grounding	T	T	T
3.3.2.7 Safety Connectors	I	-	-
3.3.2.8 Synchronization	T	T	T
3.3.2.9 Pyrotechnics and Actuators	n/a	n/a	n/a
3.3.2.10 Timing Requirements	T	T	T
3.3.3 Command and Data Handling	-	-	-
3.3.3.1 Power On/Off Commands	T	T	T
3.3.3.2 Memory Load Commands	T	T	T
3.3.3.3 Serial Digital Data	T	T	T
3.3.3.4 Health and Safety	T	T	T
3.3.4 Central Instrument Data Processor	-	-	-
3.3.4.1 Data Transfer Rate	T	T	T
3.3.4.2 CIDP Processing Requirements	-	T	T
3.3.4.3 Processing Rate	-	T	T
3.3.4.4 Uncompressed Data Storage Requirements	-	T	T
3.3.4.5 Instrument Control Functions	T	T	T
3.3.4.6 Instrument Safe Requirements	-	T	T
3.3.4.7 Preferred Protocol for Serial Interface	T	T	T
3.3.4.8 Roll Synchronization Pulse	-	T	T
3.3.5 Thermal	-	-	
3.3.5.1 Thermal Design Requirements	A,T	T	T
3.3.5.2 Thermal Design Concept	D		
3.3.5.3 Thermal Interfaces	I	-	T
3.3.5.4 Heaters	T	T	T
3.3.5.5 Thermal Finish	I	-	-
3.3.5.6 Temperature Range	-	-	-
3.3.5.7 Temperature Monitoring	T	T	T
3.3.5.8 Thermal Analysis and Predictions	A	-	T
3.4 Other Design Requirements	-	-	-
3.4.1 Environments	T	-	D

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3.4.2 Life	A	-	D
3.4.3 Reliability	A	-	-
3.4.4 Maintainability and Storage	D	-	-
3.4.5 Safety	-	-	-
3.4.5.1 Transportation Safety	I	-	-
3.4.5.2 GSE Safety	I	-	-
3.4.6 Special Materials & Processes Constraints	I		
3.4.6.1 Sensitive Components	I		
3.4.6.2 Limits	I	I	I
3.4.6.3 Protection	I	I	I
3.4.6.4 Purge Connector	I	I	
3.4.6.5 Purging	T	T	T
3.5 Special Ground Support Equipment (GSE)			
3.5.1 Mechanical GSE	D	D	D
3.5.2 Electrical GSE	D	D	
3.6 Operations Support and Training	D	D	D
3.7 Special Considerations			

4.5 Test Support Requirements

4.5.1 Facilities and Equipment

SwRI is responsible for all payload-level verification testing. Observatory-level verification activities will be carried out at LMMS by SwRI and LMMS jointly, with participation as needed by the instrument teams. Some NASA facilities may be used by instrument teams for instrument-level verifications.

4.5.1.1 Utilization of Existing Facilities and Equipment

Most of the fabrication and assembly of LENA will be performed in the clean room at GSFC, building 2, room 158. Instrument-level environmental testing will take place at GSFC's facilities in building 7 and at the magnetics test site. LENA will be calibrated at the neutral beam facility at the University of Denver. Some conversion surface research will take place at the University of Berne, Switzerland.

4.5.1.2 Establishment of Activation and Operations Plans

Activation and test plans shall be established in accordance with IMAGE project direction.

4.5.1.3 Qualification/Certification of Test Equipment

During the preparation of verification test procedures attention is given to the safety of the test article. Procedures designed for use with critical end-item hardware always require verification of the safety of the test equipment used in the test. In most cases this involves an independent measurement of interface conditions with the equipment disconnected from the end-item. Precautions are taken to insure that overvoltage conditions from a failed item of test equipment cannot stress the interface to the end-item. All test equipment requires calibration prior to use in verification testing, another step which helps reduce the possibility of improper operation. Finally, test personnel are briefed on the use of test equipment and on the flow of activities in a pre-test briefing preceding all verification tests.

5. Preparation for Delivery

5.1 Final Assembly Site

Final assembly and integration of the LENA Imager will be performed at Goddard Space Flight Center in Greenbelt, MD.

5.2 Transportation

5.2.1 Transportation Modes

Cross country transportation will be provided by an environmentally-controlled trailer/transporter which is compatible with the environmental conditioning requirements specified in Section 3.4.6. Ground transportation to and from any location will be over paved surface roadways and ramps.

5.2.2 Transport Environment

During transport, an environmental enclosure shall be in place around the Spacecraft/Observatory. During all transportation operations the LENA Imager shall be maintained within -30 and +60 C and within **0** and **15** % RH. Impact loads in all 3 S/C axes shall be as specified in Sect. 3.6.1.2 of the Spacecraft to Payload ICD. Temperature and humidity at the Spacecraft/Observatory and impact loads to the Spacecraft/Observatory shall be recorded from the time the Spacecraft/Observatory leaves the final assembly site to the time it arrives at the launch pad.

6. NOTES

6.1 Intended Use

The intended use of this specification is to document and disseminate Level 2 instrument design and verification requirements for the LENA Imager.

6.2 Meaning of Specific Words

Specific meanings are assigned to the use of words “shall”, should”, “is”, and “will” as follows:

6.2.1 Shall

“Shall” indicates a requirement to provide a function. “Shall” indicates that the requirement is mandatory and will be the subject of specific acceptance testing and compliance verification.

6.2.2 Should

“Should” indicates a desired goal for which there is no objective test. “Should” indicates that there will be an attempt to achieve the desired goal to the maximum extent feasible while remaining cost effective. Component or performance specified by statements using “should” may be subject to specific acceptance testing, but to only qualitatively assess the level of goal achievement against a specific set of test criteria.

6.2.3 Is or Will

“Is” or “will” indicate a statement of fact or provides information. Components or performance levels described by statements using “is” or “will” must not, by definition, refer to a goal or requirement.